ATLAS RPC commissioning status and cosmic ray test results

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The muon trigger system of the ATLAS experiment consists of several sub-systems and each of them need to be tested and certified before LHC operation. In the barrel region Resistive Plate Chambers [1] are employed. RPC detector and its level-1 trigger electronics are designed to detect and select high momentum muons with high time resolution and good tracking capability for a total surface of about 4000 m^2. The commissioning phase provided an unique opportunity to demonstrate, before LHC start-up, the functionality of the muon trigger components such as detector chambers, level-1 trigger electronics, detector slow control system, data acquisition chain, software and computing. We present the status of ATLAS RPC detector, the problems met during the commissioning and the solutions found and, finally, its performances as obtained by acquiring cosmic rays.

1 Introduction

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Muon identification capability and high accuracy in muon momentum measurements are crucial requirements for the ATLAS experimental program. The ATLAS Muon Spectrometer [2] was designed to achieve a standalone muon momentum measurements with good resolution, high efficiency and over a wide range of transverse momentum, pseudo-rapidity, and azimuthal angle. RPC were chosen as muon trigger detector for the barrel region (up to abs(η)=1). They are gaseous detectors operated at atmospheric pressure, covering about 4000 m^2 and arranged in three concentric layers, each one consisting of two active gas volumes.
The on-line muon selection algorithm is based on fast measurement of charged particle trajectory deflections due to the magnetic field. By measuring the deviation of the trajectory from the straight line ("infinite momentum track") interpolated from the interaction point to the middle RPC layer (Figure 1), one can estimate the curvature of the charged particle trajectory in the toroidal magnetic field.
The trigger selection algorithm is based on the definition of allowed geometrical roads (*Coincidence Windows*) around the infinite momentum track projected on the inner and outer RPC layers (respectively Low-p_t and High-p_t planes in Figure 1).
In the ATLAS barrel sub-system two muon trigger thresholds are chosen:

1) Low-p$_t$ muon triggers ($6 < p_t < 20$ GeV) built-up from coincidence signals coming only from the middle RPC station and requiring a 3 out of 4 majority logic.
2) High-p$_t$ muon triggers ($>$ 20 GeV) built-up only in presence of a Low-p$_t$ trigger and requiring in addition a spatial coincidence with the outer chamber with a 1 out of 2 majority logic.

The system was designed with 3 p$_t$ programmable thresholds applied in parallel, both for Low-p$_t$ and High-p$_t$. The lower available p$_t$ threshold value is limited by the cabling and it corresponds at about 5 GeV.

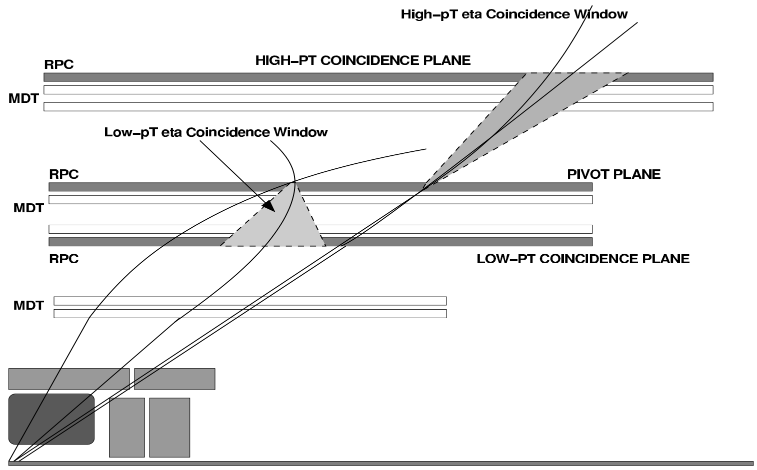

Figure 1: Level-1 muon trigger algorithm in the ATLAS barrel region implemented by three RPC layers.

2 ATLAS RPC commissioning

In order to assure the proper functionality of the apparatus, each hardware and software component was subject to several tests. Due to the high level of interdependence between different parts: gas system, electrical service cabling, power system, slow control system, data acquisition and off-line monitoring, a well defined commissioning schedule was followed and specific diagnostic tools were used.

2.1 Hardware components commissioning

The hardware commissioning can be divided in three main parts: **gas system, electrical service cabling and power system**.

- **Gas system**: The gas system is a recirculating system with a constant fraction of fresh gas mixture at the input. The total amount of gas volume, including also

the gas pipes, is about 18 m^3. The gas mixer, humidification and purification modules and the gas analysis apparatus are located on surface, while in the experimental cavern are located the 5 distribution gas racks for a total number of 128 gas lines.
During the commissioning each gas line was checked at every step to avoid the presence of gas leaks. About 1 % of the gas inlets glued on the volume inside the chambers were found broken after the installation phase. The most accessible ones were repaired, the 22 gas volume, on about 4000, with the remain gas inlets broken were isolated from the gas manifold and disconnected from the high voltage distribution system. These few gas inlet will be repaired during the winter shutdown.
A gas chromatography facility was installed on surface building in order to monitor the gas mixture purity and composition. Since May 2008 the gas system is complete and working in a stable way in recirculating mode.

- **Electrical service cabling**: A huge amount of work was done in the experimental cavern to connect each RPC chamber and level-1 trigger tower to the electrical service cables in order to power the detector.
  All electrical cables were tested on both sides, before the connection to the chambers and racks, using specific tools made available by the DCS software. This procedure reduced significantly the amount of mapping errors of such a complicated system. Before the cavern closure for LHC start-up, all standard RPC chambers were cabled and tested by cosmics, special RPC chambers (less than 5 % of the total coverage) will be connected and tested during the winter shutdown.

- **Power system**: In order to power all the RPC chambers and level-1 trigger towers, a complex power system was setup in the service and experimental caverns. In the service cavern three 1527 CAEN mainframes control by 17 branch controller modules, all the electronic boards directly installed in the experimental cavern. In the experimental cavern 29 racks were arranged, each one containing several crates were the electronic boards are located. To assure the correct operations and control of every electronic board, each crate must be powered by two separate 48 volt power lines, one for the control system and the other one for the power distribution.
  To provide the power distribution twenty four 3486 CAEN generators were installed in the experimental cavern, while for the control line two 3485 CAEN generators were installed in the service cavern. The control lines are back-up against utility power cut by a Uninterruptible Power Supply (UPS) system. The ATLAS RPC and level-1 power system uses about 300 electronic boards, all of them installed, tested and connected to the final distribution power system.

2.2 Software components commissioning

The software parts could be divided in two separate components: **DCS** and **DAQ**, which interact directly with the hardware of the apparatus, and the **off-line software**, which accurately monitor the detector performances.

- **DCS and DAQ system:** The RPC Detector Control System (DCS) is implemented as a finite-state machine in a common ATLAS framework that allows slow control and monitoring of the detector. The DCS commissioning had followed in parallel the hardware commissioning of the system, leading its evolution. Since the first ATLAS combined run period RPC DCS was employed extensively through its Graphical User Interface (GUI) thanks to its advanced stage. The full service chain is remotely controlled and monitored from the ATLAS counting room in the same integrated framework. In particular, the end-user can manage in a simple way all RPC and trigger electronics parameters and voltage supplies, and monitor the gas system parameters and environmental quantities. A direct connection to on-line database is implemented and the automatic data archive is under implementation. The RPC detector is fully integrated in the ATLAS level-1 trigger and data acquisition systems. It routinely provides cosmic ray triggers for the other sub-detectors, during combined data taking periods. The corresponding trigger rates are directly related to the position and orientation of the operated trigger towers with respect to the main shafts, where most of the cosmic rays are coming. Trigger roads were implemented in both views for most of the trigger towers before the LHC startup. Up to now RPC triggers were delivered to the MCTPI (Muon Central Trigger Processor Interface) for Low-p_t trigger conditions in the non-bending view only. Muon triggers will be delivered for both views after the fine RPC time calibration. Since spring 2008, several high rate tests were performed and RPC level-1 trigger system were able to provide trigger up to 100 kHz, which corresponds to the running conditions for the ATLAS 2009 upgrade.

- **Off-line analysis software**: RPC off-line data analysis is performed in the ATLAS standard software framework named ATHENA [3]. During the commissioning the off-line code was optimized and debugged by real cosmic rays data. The readout channel mapping were cross checked and accurately verified to describe the hardware. Being a part of the Muon Off-Line Monitoring package, the RPC monitoring code automatically runs at the CERN Tier0 facility, where data are processed just after being available on the central data storage. Run by run all relevant quantities characterizing the RPC detector are measured such as efficiency, cluster size and noise. Moreover, general and specific plots are stored and displayed on the web to asses the RPC data quality.

3 Cosmics ray test results

Since Fall 2006 cosmic muons were acquired with the ATLAS muon spectrometer [4]. This intense activity allowed to debug and characterize the RPC detector in an extensive way. In Figure 2 the RPC readout strip cluster size and detection efficiency measured by cosmic rays during commissioning are shown.

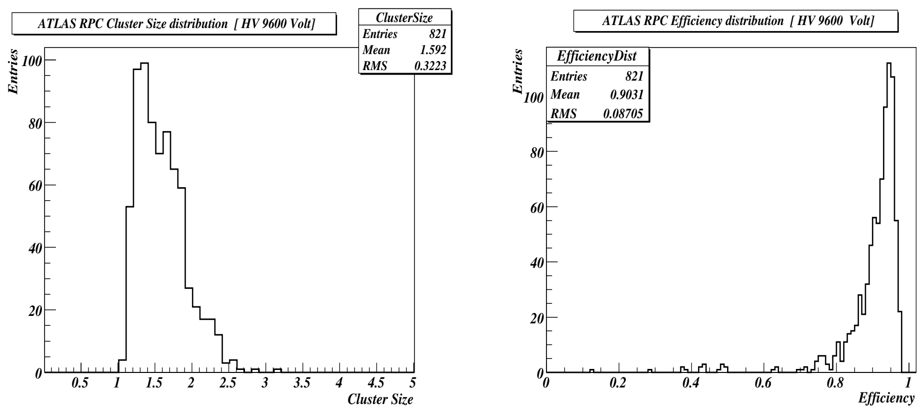

Figure 2: Distribution of the RPC readout strip panel average cluster size and detection efficiency for a high voltage of 9600 V and nominal voltage front-end threshold (T=20 ^{0}C and P= 980 mbar).

By then onwards we participated at several ATLAS combined data taking periods before LHC start-up. Over a year's work with cosmic rays enabled to characterize all the muon spectrometer aspects and verify its functionality. In particular, correlations between precision tracking chambers and trigger chambers were extensively studied in order to verify if data corruptions and synchronization problems were presents (see Figure 3.a).

In Figure 3.b is shown the extrapolation on the earth surface of the RPC-only tracks reconstructed with the RPC off-line monitoring, The plot shows that most cosmic muons reach the experimental cavern going through the two main conduits used to lift down the single components of the apparatus (located along the z=0 axis), but some of them are coming from the two secondary conduits hosting service lifts (located along the x=0 axis).

4 Conclusions

The ATLAS RPC commissioning was completed before LHC start-up. All hardware and software elements were installed, verified and certified, allowing a wide use of

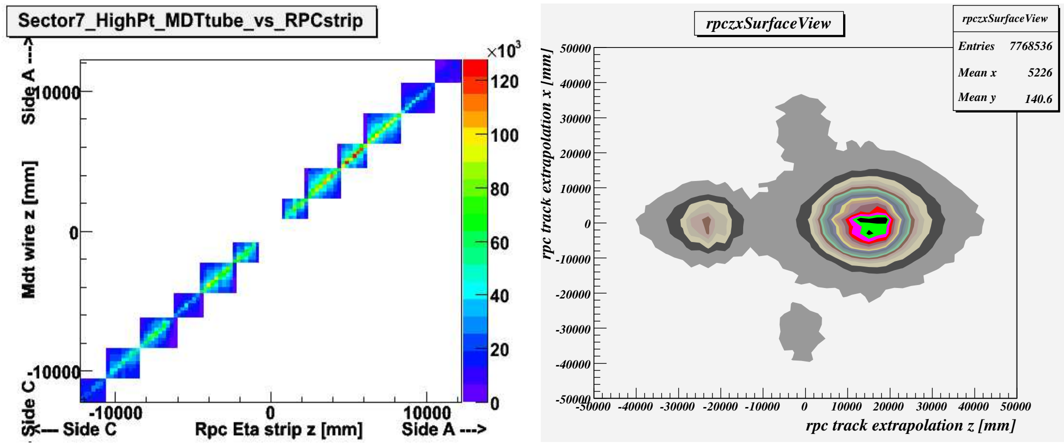

Figure 3: Hit spatial correlation along the beam (z axis) of adjacent MDT multi-layers and RPC planes (a). Extrapolation on surface of the cosmic muon triggered and reconstructed by the ATLAS RPC detector. In addition to the two main ATLAS shaft (z=0 axis), the ATLAS service lifts are also clearly visible (b).

the detector as cosmic ray trigger source for all ATLAS commissioning. Nevertheless, during the winter shutdown further RPC detector improvements are scheduled.

5 Acknowledgments

We are indebted to the RPC/LVL1 technical staff for their highly qualified contribution in designing and setting up the whole system. We are grateful to the CERN technical staff for the continuous and promptly support during detector installation and commissioning phase.

References

[1] R. Santonico R. Cardarelli: **Development of resistive plate counters.** Nuclear Instruments and Methods, 187 (1981) 377.

[2] ATLAS Muon Collaboration, **ATLAS Muon Spectrometer Technical Design Report**. CERN/LHCC/97-22, (1997).

[3] ATLAS Computing Group, **ATLAS Computing Technical Design Report**. ATLAS TDR-017, CERN/LHCC/2005-022, (2005).

[4] G. Chiodini, *et al.* **" RPC cosmic ray tests in the ATLAS experiment"** Nuclear Instrum.Meth.A 581 (2007) 213-216.